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DEPARTMENT OF THE NAVY
COMMANDER OPERATIONAL TEST AND EVALUATION FORCE
7970 DIVEN STREET
NORFOLK, VIRGINIA 23505-1498

3980 (190-04-OT-IIIC)
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From: Commander, Operational Test and Evaluation Force
To: Chief of Naval Operations

Subj: FOLLOW-ON OPERATIONAL TEST AND EVALUATION OF THE NAVSTAR GLOBAL POSITIONING SYSTEM AIR INTEGRATION/INSTALLATION PROGRAM (OPNAV REPORT SYMBOL 3960-12)

Ref: (a) Test and Evaluation Master Plan 190-4 (Rev 1) of 11 May 92
(b) Test and Evaluation Master Plan 190-4 (Rev 1) Change 1 of 15 Jun 92
(c) COMOPTEVFOR ltr 3960 (934-2-OT-IIIB/190-4-OT-IIIC) Ser 631/C052 of 22 May 92
(d) CNAWCAD Patuxent River, MD 051339Z Aug 92
(e) Navy GPS User Equipment Air Set Maintainability/Built-in-Test Assessment Test Report of 28 Sep 89
(f) ASD memo of 13 Sep 91

1. Summary. This is a report of COMOPTEVFOR's first phase of follow-on operational test and evaluation (OT-IIIC), as defined in references (a) and (b), of the Global Positioning System (GPS) as installed in the ES-3A, performed under CNO Project 190-4. The purpose of the evaluation was to determine the reliability, maintainability, and availability of the AN/ARN-151 GPS User Equipment, as installed in the ES-3A, in an aircraft carrier environment. The GPS user equipment (UE) is determined to be operationally suitable. Approval for extension of application to platforms which require catapult launches and arrested landings is recommended.

2. Background. The ES-3A integration of the GPS is designed to provide precise navigation positioning data, accurate velocity and time data and to enhance night/adverse weather mission capability. Additionally, GPS provides a sole means of navigation capability for flight in the National Airspace System (NAS), by emulating the current Tactical Air Navigation system. The GPS UE required for aircraft integration consists of a receiver processor unit, an antenna system and a control display unit. The AN/ARN-151(V) receiver acts as the GPS system receiver and associated avionics are integrated into the on-board mission computer.

3. Program History

a. OT-IIB (A-6E) was conducted from September 1985 to March 1986. The system was operated by fleet personnel and maintained by contractor personnel. COMOPTEVFOR concluded that the NAVSTAR

GPS UE was potentially operationally effective and potentially operationlly suitable, and recommended limited production and limited fleet introduction.

b. OT-IIC (SH-60B) operational evaluation for the AN/ARN-151(V) was conducted from July to December 1989. The system was operated and maintained by fleet personnel. COMOPTEVFOR concluded that NAVSTAR GPS UE was operationally effective and potentially operationally suitable, and recommended limited production and fleet introduction in naval helicopters not having software-intensive applications requiring integrated capability.

4. Project Operations. Project operations were conducted with two production representative aircraft from 20 August to 20 November 1992 in accordance with reference (c). The two ES-3A aircraft, with GPS UE installed, were operated in the NAS, during long-range overwater transits and while deployed in an aircraft carrier environment for a combined total of 355.3 flight hours in 121 sorties. During OT-IIIC, the GPS UE was subjected to 64 catapult launches and 64 arrested landings.

5. Scope of the Evaluation

a. Objectives. The purpose of OT-IIIC was to determine the reliability, maintainability, and availability of the AN/ARN-151 in an aircraft carrier environment as installed in the ES-3A.

b. Evaluation Criteria. The following minimum acceptable operational performance requirements were specified in references (a) and (b):

Operational Suitability		Threshold
Reliability	Mean Flight Hours Between Critical Failures-GPS ($MFHBCF_{GPS}$) (Note 1)	≥500 hr
Maintainability	Organizational level (O-level) Mean Time to Repair-GPS (O-level $MTTR_{GPS}$) (Note 2)	≤20 min
	Intermediate level (I-level) Mean Time to Repair-GPS (I-level $MTTR_{GPS}$) (Note 3)	≤60 min
Availability	GPS Availability (A_{GPS}) (Note 4)	≥0.95

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Notes:

1. $MFHBCF_{GPS}$ was calculated using the formula:

$$MFHBCF_{GPS} = \frac{\text{Total Number of Flight Hours}}{\text{Total Number of Critical GPS Failures Discovered During System Operations}}$$

Where, critical GPS failure is any fault, failure, malfunction, or degradation of any component or function which prevents successful accomplishment of the mission task. Critical failure determination was based on Appendices A and B (proposed ES-3A Mission Essential Systems Matrix of reference (c), current fleet doctrine, and the operational test director's operational experience.

2. O-level $MTTR_{GPS}$ is the mean time to complete corrective maintenance on all critical hardware failures. It is the average time to self-test, remove and replace faulty weapons replaceable assemblies, exclusive of access time.

3. I-level $MTTR_{GPS}$ is the mean time to test, isolate, remove, and replace the faulty shop replaceable assembly (SRA).

4. A_{GPS} is a measure of availability of the GPS, and was computed using the following formula:

$$A_{GPS} = \frac{\text{GPS Uptime}}{\text{GPS Uptime + GPS Downtime}}$$

Where, GPS Uptime is that amount of time where the ES-3A Mission Avionics System (MAS) is indicating that a usable GPS signal is being received. GPS downtime is that total time that the system was operating and during which the computer indicates a source other than GPS is providing primary positional information to the MAS.

c. Limitations. The following limitation affected testing, but did not impact the resolution of COIs and did not preclude the formulation of conclusions concerning operational suitability: The GPS was not tested in all operational environments. Testing took place at electronic warfare ranges and in-theater. Data was correlated to all operational environments.

6. Critical Operational Issues. COIs were resolved as follows:

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Critical Operational Issue	Resolution
Reliability	Resolved (SAT)
Maintainability	Resolved (SAT)
Availability	Resolved (SAT)

7. Results and Discussion. Operational suitability test results are:

a. Reliability. The GPS system installed in the ES-3A was operated for 355.3 flight hours with zero mission critical failures (criterion: ≥500 hours). Since the same GPSs were tested during the ES-3A's Technical Evaluation (DT-IIIC) the reliability data reported in reference (d) has been considered in determining overall system $MFHBCF_{GPS}$. Table (1) lists the number of flight hours logged during both the DT and OT phases of testing, by aircraft.

Table 1. U. Reliability

AIRCRAFT	DT-IIIC	OT-IIIC	TOTAL HOURS BY AIRCRAFT
JA-770 (159401)	177.5	164.9	342.4
JA-771 (159404)	24.7	190.4	215.1
TOTAL HOURS BY PHASE OF TESTING	202.2	355.3	557.5

There were zero system failures during DT-IIIC. Based on the cumulative number of flight hours logged during DT-IIIC and OT-IIIC, as well as the reliability demonstrated by GPSs integrated into various other air platforms, there was no reason to suspect that the reliability will be significantly less than 500 hours.

b. Maintainability.

(1) No critical failures occurred at the O-level (criterion: ≤20 minutes). Repair of one critical failure induced during a maintenance demonstration (M-demo) required a total of 6 minutes to complete. Only one maintainability demonstration was conducted because this was a remove and replace

assembly at the O-level. The procedures were found adequate. The M-demo was assessed as satisfactory.

(2) No critical failures occurred at the I-level (criterion: $\leq$60 minutes). Repair of 28 mission critical faults induced during a maintainability/built-in-test assessment (reference (e)) required a total of 10.6 hours to complete, for an $MTTR_{GPS}$ for I-level of 22.8 minutes. The AN/ARN-151 (V) receiver is the only GPS component installed in the ES-3A that is capable of being repaired at the Intermediate Maintenance Activity.

c. Availability. The demonstrated A_{GPS} was >0.99 (criterion: $\geq$.95) based upon 355.3 flight hours of GPS uptime in 355.3 total flight hours of GPS uptime and no downtime.

8. Operational Considerations. GPS Receiver (P/N 622-8078-020) did not accept cryptographic key on any attempt to load it. Although not an objective of this test, this effectiveness problem was detected during testing. Without the crypto key, the GPS cannot operate with full precise position service (PPS) capability. PPS provides accurate navigation in 3 dimensions to within 16 meters spherical error probable. This capability is defined as a requirement in accordance with the minimum avionics requirements (MAR) promulgated by the Assistant Secretary of Defense (reference (f)). Without the cryptographic coding the GPS will be subject to degraded navigational accuracy as well as degraded capability to reject interference, jamming, spoofing and meaconing. As a work-around for testing purposes, the batteries of the receiver were removed. This procedure erases the internal memory but allows the cryptographic key to be loaded. The GPS then requires a cold start. A GPS cold start forces the receiver to search for satellites without almanac data. The cold start process requires in excess of 20 minutes to reacquire GPS position data. A normal start requires approximately 2 minutes. The excessive time of a cold start could prevent a GPS solution from being available to the aircrew in the event of an alert launch. This problem appears to be unique to the 020 receiver, but not unique to the ES-3A. It has also occurred on the E-2C equipped with the 020 receiver. It has not been observed in the later 030 and 040 receiver integrations. OT-IIIC was not intended to resolve MAR compliancy in the ES-3A. This will be verified during FOT&E.

9. Conclusions. The GPS UE, as installed in the ES-3A, is operationally suitable.

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10. Recommendation. Extension of application for the AN/ARN-151(V) GPS system is recommended for platforms in the aircraft carrier environment (i.e., catapult launches and arrested landings).

11. Other Recommendations. Ensure correction of cryptographic key loading problem discussed in paragraph 8.

V. L. HILL JR.

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